
An Improved U-Slot Based 1 X 2 Triple Band Antenna Array for Flying Ad-hoc Networks (FANETs)

By

B. O. Sadiq¹, O. S. Zakariyya¹, S. A. Olayanju², A. E Adedokun²

^{1,2}Department of Computer Engineering,
Ahmadu Bello University Zaria

^{1,2}Department of Electrical Engineering,
University of Ilorin Kwara

Email: bosadiq@abu.edu.ng,

ABSTRACT

The objective of this paper is to design an improved U-Slot based 1 X 2 triple band antenna array for Flying Ad-hoc Networks (FANETs). The purpose of this modification is to increase the bandwidth and gain of the existing 1 X 2 triple band antenna array. This is because high bandwidth and gain are essential requirement for UAVs in FANET. However, to achieve this, the resonating frequency needed to be selected appropriately. The proposed antenna array resonates at 3.2GHz, 5.1GHz and 6.4GHz frequency band respectively. The antenna is optimized using a U-Slot resonating at triple-bands by introducing two symmetrical slits at the non-radiating edges of the patch. Simulation results were achieved using CST Studio and showed that the antenna has a bandwidth of 313MHz, 51MHz and 167MHz for the three bands respectively. This implies that practical applications can be achieved using this antenna.

Keywords: FANETs, Wireless networks, Antenna, Triple band

INTRODUCTION

The present world is tending towards the use of Unmanned Aerial Vehicles (UAVs) in every aspect of life. The use of UAV has now frequently been applied to both military and civilian applications. Some of these military and civilian applications are live video coverage, broadcasting, photography, remote-sensing, search and rescue operations disaster monitoring amongst others (Bekmezci *et al.*, 2013; Markwalter 2015; Bilal *et al.*, 2016). However, for these applications to be realizable, there is a need to design a UAV antenna that will serve as a transmitter between the scene and the satellite or base station as well as between two UAVs. In the design of a UAV antenna, the size, weight and shape of the antenna must be considered due to the UAV payload constraints. The antenna shape must complement the UAV aerodynamics, small size and weight without negative impact on the overall design (Temel *et al.*, 2014). Nonetheless, it is essential to note that a fundamental requirement in antenna design for UAVs that will form

Flying Ad hoc Network (FANET) is that it must be highly directional with large bandwidth and gain. Flying ad-hoc networks (FANETs) which comprised of multi-UAVs is a network where only a sub-group of UAVs communicate with the base station and all the UAVs form an ad-hoc network (Bilal *et al.*, 2016; Tareque *et al.*, 2015). Multi-UAVs systems has a lot of advantages over the single UAV system. Some of which are: smaller maintenance cost, fast and efficient information dissemination amongst others. (Bekmezci *et al.*, 2013; Tareque *et al.*, 2015). Quite a number of researchers have developed different types of antenna for use in UAVs for FANET application such as the work of (Wong *et al.*, 2012; Razzaqi *et al.*, 2013; Huynh & Lee (1995); Ali *et al.*, 2015). The authors justified why the use of Low-profile planar microstrip patch antennas (MPAs) are typically preferred and most suitable for FANET. The reason being that it is small in nature, has lesser weight and is easy to fabricate. However, it poses a challenge which is the low bandwidth and gain. But recently, efficient and reliable

MPAs have been proposed by the works of (Sharawi *et al.*,2010; Trotta *et al.*,2014; Razzaqi *et al.*, 2014; Alonso *et al.*, 2015). These antennas were embedded in the UAVs for better performance. Study suggested that embedded antennas offered improved performance for UAV communication. As such, 1 X 2 printed antenna array for use in multi-UAVs communication in next generation FANETs has been design by (Khawaja *et al.*, 2014) and fabricated by Bilal *et al.*, (2016). However, the performance of this

antenna can significantly be improved using a U-slot as presented in this paper.

Hence, the objective of this paper is to improve the work of Bilal *et al.*, (2016) in terms of bandwidth and gain using a U-slot. Figure 1 shows the Fabricated prototype of the 1 X 2 triple-band MPA array in the work of Bilal *et al.*, (2016)

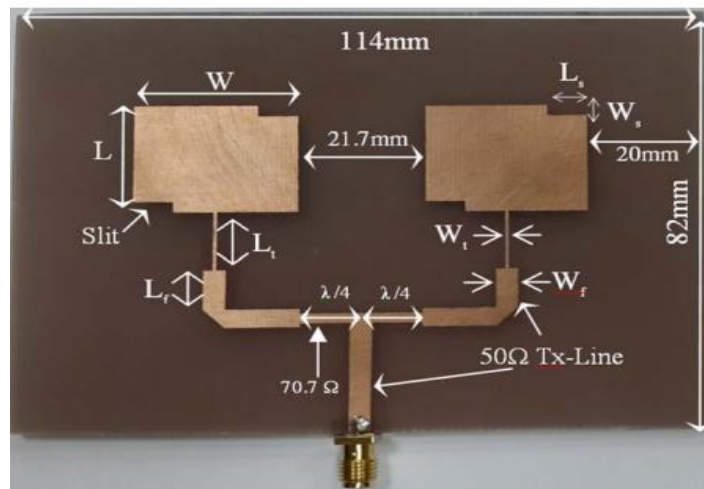


Figure 1: Fabricated prototype of the 1 X 2 triple-band MPA array in the work of Bilal *et al.*, (2016)

Table 1 shows the dimensions used in designing and fabricating the 1 X 2 MPA Array (Khawaja *et al.*, 2014; Bilal *et al.*, 2016)

Table 1: Dimensions used in Designing and Fabricating The 1 X 2 MPA Array

Parameter	Size
Patch length (L)	20.4mm
Patch width (W)	20.6mm
Slit length (Ls)	8mm
Slit width (Ws)	2mm
QW transformer length (Lt)	10.9mm
QW transformer width (Wt)	0.5mm
Tx-line length (Lf)	21.9mm
Tx-line width (Wf)	3.29mm

ANTENNA DESIGN

Following the work of Bilal *et al.*, (2016) in order to replicate the existing design, the proposed modification with U-slot of the 1 X 2 triple-band MPA

array elements have similar dimensions like the previously designed single-element MPA. The mathematics governing the design are as presented in design procedure briefly discussed in (Khawaja *et al.*,

2014). The design of the proposed antenna was carried out using the CST Studio 2016 software. For the purpose of comparison, radiation patterns were generated. The 1 X 2 antenna array design process started with rectangular patch antenna operating at 3.6 GHz as already presented in both the work of (Bilal *et al*, 2016) and (Khawaja *et al.*, 2014). But in order to improve the bandwidth, which is a critical requirement

for UAVs in FANET, their design was improved using a U-slot. However, using the U-slot require the selection of a more appropriate resonance frequency. As such, the starting frequency used for this work was 3.2GHz. Table 2 shows the performance comparison in the work of (Bilal *et al*, 2016) and that proposed in this paper.

Table 2: Comparison of the work of (Bilal *et al*, 2016) and proposed

Frequency (GHz)	Bilal <i>et al</i> , (2016)			Proposed		
	3.6	5.2	6.7	3.2	5.1	6.4
S ₁₁ (dB)	-15.7	-15.3	-31.5	-31	-18	-37
10 dB						
Bandwidth (MHz)	130	123	180	313	51	167

Based on the Figure 1, the proposed antenna design with the U-slot operating at frequencies of

3.2GHz, 5.1GHz and 6.4GHz is depicted in Figures 2 and 3

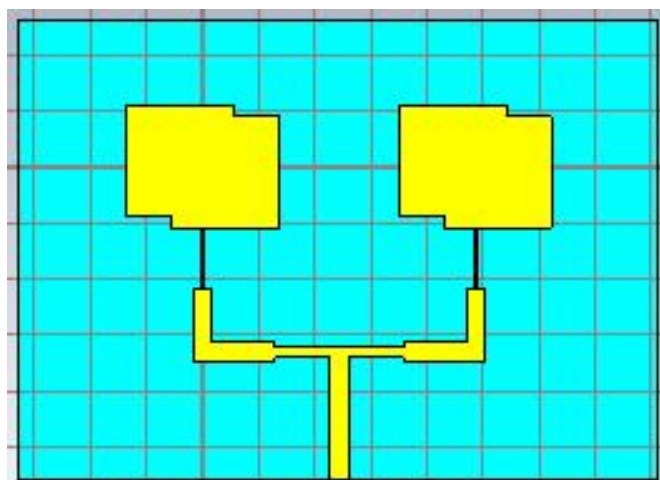


Figure 2: Front View of the proposed Antenna

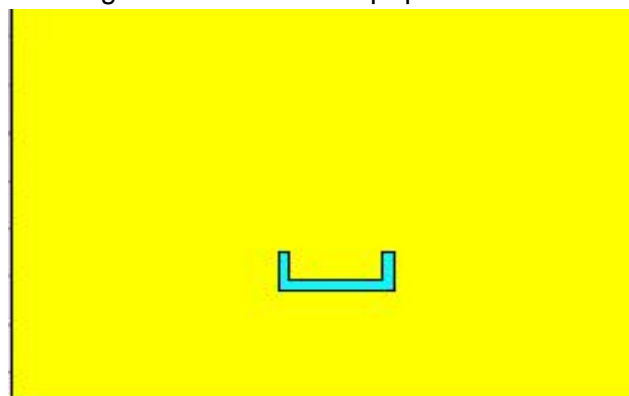


Figure 3: Ground Plane with U Slot.

The return loss plot of the proposed design is depicted in Figure 3

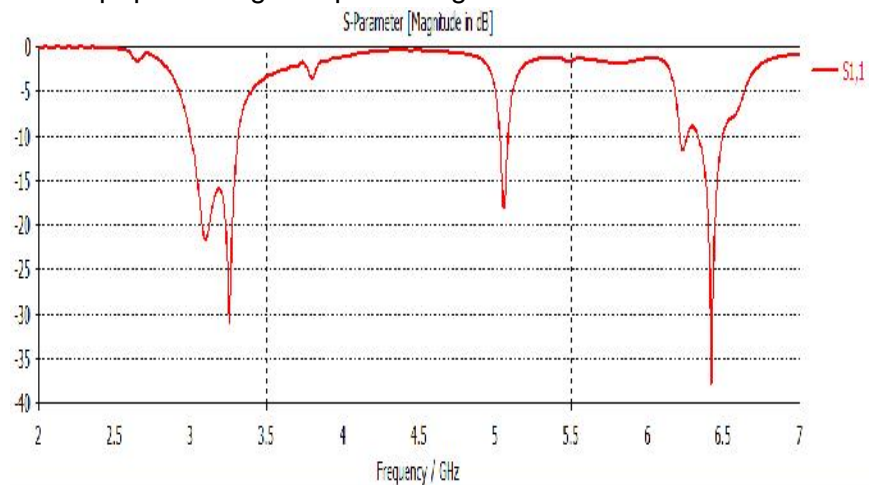
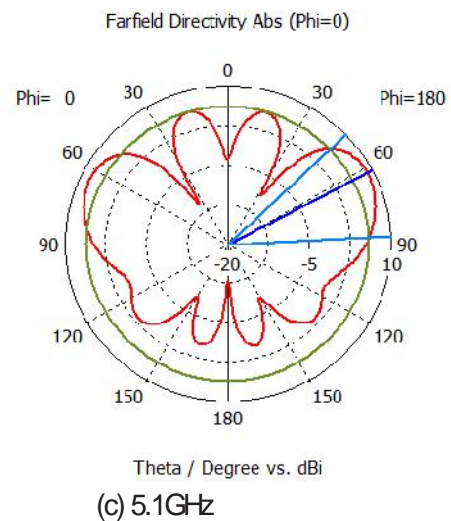
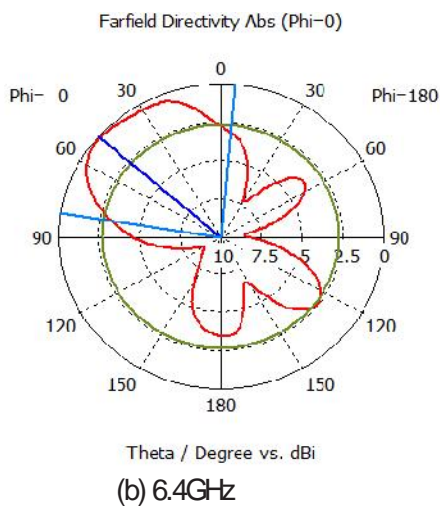
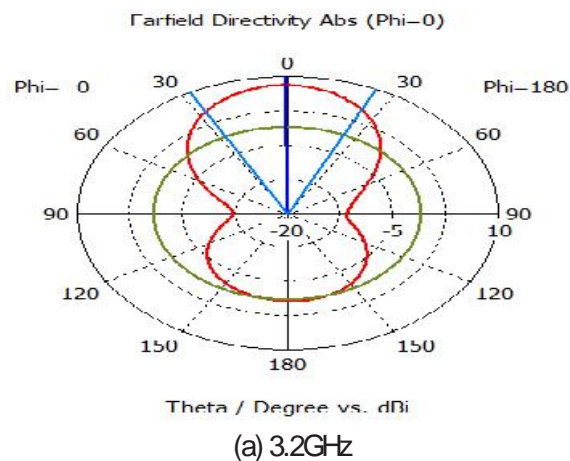


Figure 3: Return loss plot for the proposed design

The radiation patterns of the antenna operating at the three frequencies 3.2GHz, 5.1GHz and 6.4GHz is as presented in Figure 4(a-c)



RESULT AND DISCUSSION

The resonating frequencies used in the work of Bilal *et al.*, (2016) differs from the proposed. This is largely due to the modification using a U-slot with a view to increasing the bandwidth and gain. As such, the comparison between them in terms of bandwidth and gain for the three frequencies are presented in Table 2. The S_{11} (dB) results in Table 2 shows that both the designed and proposed 1 x 2 triple-band MPA array have good impedance matching as desired. But, the bandwidth for the proposed is far improved at 3.2GHz. From the result presented in Table 2, it can be observed that the impedance bandwidth achieved in the proposed design at 3.2GHz is more than twice that achieved at 3.6GHz in the developed design.

The 2D radiation patten for the 1 x 2 triple-band MPA array at their respective frequencies are already presented in the work of Bilal *et al.*, (2016). The 2D radiation patten of the proposed design are generated in the CST Studio simulation software. The results are presented in Figure 4(a-c) respectively at 3.2GHz, 5.1GHz and 6.4GHz. It can be seen that the proposed 2D radiation patterns are the horizontal expurgated of the 3D radiation pattern at 0° to 360° with finite ground plane resulting in some back lobes in the radiation pattern as depicted in Figure 4(a-c).

CONCLUSION

A 1x2 improved U-slot triple-band MPA array has been proposed in this paper. Simulations result shows that the proposed antenna exhibit a triple band of operation having bandwidth for return loss (S_{11}) of -31dB, 313MHz at 3.2GHz, -18dB, 51MHz at 5.1GHz and -37dB, 167MHz at 6.4GHz which are applicable to Flying Ad Hoc Networks (FANETs). The antenna was design using the CST studio software. Further work should validate the obtained simulated result by fabricating the antenna design.

REFERENCES

Ali M., Khawaja B.A., Tarar M.A., and Mustaqim M (2015). A dual band U-slot printed antenna array for LTE and WiMAX applications, Wiley

- Microwave Opt Tech Lett 55, pp. 2879–2883. Retrieved from <http://shcolar.google.com.ng> May, 2017
- Alonso J.M.I. and Perez M.S. (2015). Phased array for UAV communications at 5.5GHz, IEEE Antenna Wireless Propagation Letters pp.771–774.
- Balanis, C.A (2005). Antenna Theory: Analysis and Design, 3rd ed., Wiley Inc, USA,
- Bekmezci I., O.K. Sahingoz, and S. Temel, Flying ad-hoc networks (FANETs) (2013): A survey, Ad Hoc Networks, pp.1254–1270
- Bilal A. K, Munir A. T, Tauseef T. Faisal A., and Muhammad M (2016). A 1 X 2 triple-band printed Antenna array for use in next Generation flying ad-hoc Networks (FANETs). Microwave and optical technology letters, 58(3). Retrieved from <http://scholar.google.com.ng> May, 2017
- Huynh T and Lee K. F. (1995). Single-layer single-patch wideband microstrip antenna, Elect Lett 31 (1995), pp.1310–1311. Retrieved from <http://shcolar.google.com.ng>
- Khawaja B.A., Razzaqi A.A., Ramzan M., Zafar M.J, Nasir S.A., Mustaqim M., Tarar M.A. and Tauqeer T. (2014). A triple-band antenna array for next generation wireless and satellite based applications, Cambridge International Journal of Microwave Wireless Tech, pp.1–10.
- Markwalter B. (2015). Flights of fancy: Products in the unmanned systems marketplace, IEEE Consumer Electron Magazine pp.46–48. Retrieved from <http://ieeexplore.org> July, 2016
- Razzaqi A.A, Mustaqim M, and Khawaja B.A (2013). Wideband E-shaped antenna design for WLAN applications, IEEE International Conference on Emerging Tech. (ICET 2013), Islamabad, Pakistan, 9-10 Dec 2013. Retrieved from <http://shcolar.google.com.ng>
- Razzaqi A.A., Mustaqim M. and Khawaja B.A. (2014). Antenna array design for multi-UAVs communication in next generation flying

- ad hoc networks (FANETs), 11th International Conference on High Capacity Optical Networks and enabling/Emerging Tech (HONETPFE), UNC Charlotte, North Carolina, 15–17 Dec 2014. Retrieved from <http://scholar.google.com.ng> June, 2017
- Sharawi M.S., Alofi D.N., and Rawashdeh O.A. (2010). Design and implementation of embedded printed antenna arrays in small UAV wing structure, IEEE Trans Antennas. Retrieved from <http://ieeexplore.org>. July, 2016
- Tareque H., Shohrab H, Mohammed A., (2015). On the Routing in Flying Ad hoc Networks. Proceedings of the Federated Conference on Computer Science and Information Systems, 5(1), pp. 1–9
- Temel S. and I. Bekmezci, Scalability analysis of flying ad hoc networks (FANETs) (2014): A directional antenna approach, IEEE International Black Sea Conference on Communications and Networking (BlackSeaCom), Odessa 27–30 May 2014, pp. 185–187.
- Trotta F., Manna A., and Scorrano L. (2014). A small lightweight wideband printed dipole for UAV applications, 2014 IEEE Antennas and Propagation Society International Symposium (APSURSI), Memphis, TN, 6–11 Jul 2014, pp. 1582–1583
- Wong H., Luk K.M, Chan C.H., Xue Q., So K.K, and Lai H.W. (2012). Small antennas in wireless communications, IEEE proceedings pp. 2109–2121.